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All-optical equalization of power transients on four 40 Gbit/s WDM channels using a fiber-based device

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Abstract

Simultaneous transient suppression of four transient-impaired 40 Gbit/s RZ-ASK WDM channels is demonstrated. Sensitivity improvements are in excess of 5 dB and transmission penalties are significantly reduced.

Introduction

The use of add/drop multiplexers and optical cross connects in modern reconfigurable networks puts severe demands on the dynamic properties of the network amplifiers. If the amplifier gain is not controlled at channel-level, channel add/drops cause network amplifiers to respond with power transients at its output [1]. Transients are known to build-up along both erbium- and Raman-amplified transmission links [2,3]. The induced sensitivity penalties [4] are particularly significant in high bit rate systems of 40 Gbit/s and beyond, where small power margins are a serious constraint. By clamping the gain or using feed-forward control of the pump powers, the average amplifier gain can be controlled to some extent [1]. However, on an individual channel basis, a robust method to mitigate the influence of transients in high-speed WDM systems is still needed [5].

In this work, a new all-optical transient equalizer based on self-phase modulation in highly nonlinear fiber (HNLF) and on-carrier optical filtering is proposed and demonstrated on four 40 Gbit/s WDM channels. Some advantages include no polarization dependence, as well as passive and ultrafast operation (no patterning at 40 Gbit/s). When the equalizer is used before transmission, the transmission penalty is also significantly reduced, after transmission through an 80 km amplified span.

Device principle and experimental setup

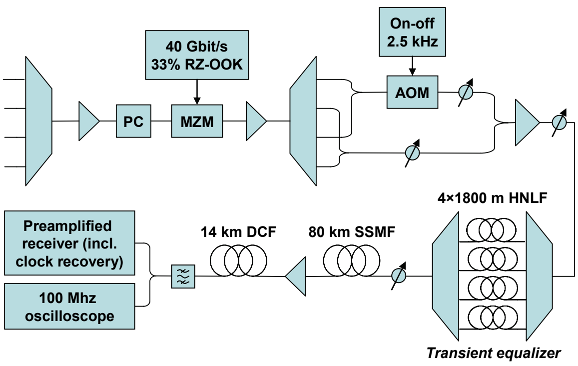


Figure 1: Experimental setup

The setup, used to simultaneously equalize the 4×40 Gbit/s channels, is shown in Fig. 1. Four laser sources, located between 1552.4 nm and 1557.2 nm with 200 GHz spacing, are multiplexed together in an arrayed waveguide grating (AWG). The 40 Gbit/s, 33% RZ-OOK signal is encoded with a PRBS sequence of 2^{31}-1 using two cascaded Mach-Zehnder modulators (MZM). After subsequent amplification, the channels are demultiplexed and combined, so that channel no. 1 and 3 are fed into an acousto-optic modulator (AOM) and on-off modulated with repetition frequency of 2.5 kHz. All four channels are then recombined and fed into a current-controlled EDFA, where the time-varying input power generates transient crosstalk between the channels.

Fig. 2 shows the channel spectrum measured at the output of the transient-generating EDFA. The disturbing, or switched, channels are named ‘$Dist_1$’ and ‘$Dist_2$’, while the surviving, or non-switched, channels are named ‘$Data_1$’ and ‘$Data_2$’. The powers of the disturbing channels are ~4 dB lower than the data channels and this is mainly due to the on-off modulation of the disturbing channels.

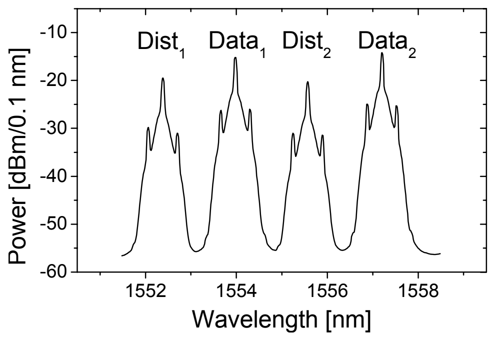
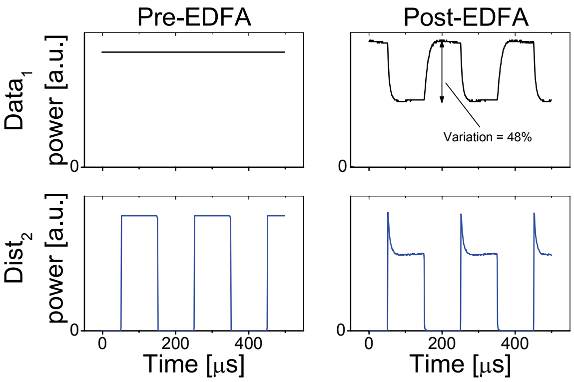


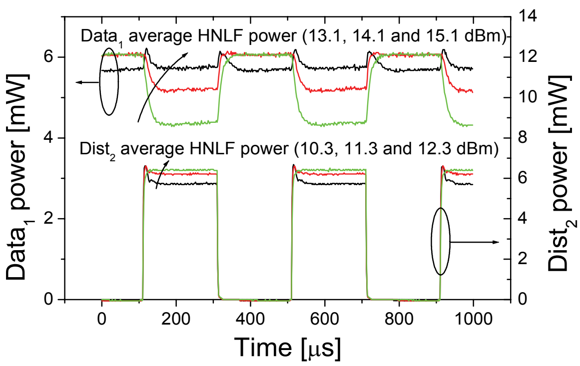
Figure 2: Channel spectrum before equalization

The transient equalizer consists of two AWGs, where each channel is interconnected by 1800 m highly nonlinear fiber (HNLF). The nonlinear coefficient of the fiber is 10 $(W \cdot km)^{-1}$ and the dispersion at 1550 nm is -0.5 ps/nm/km. If the pulse power into the HNLF is sufficiently high, the self-phase modulation causes the spectrum of the pulse to broaden. The high power pulses hence give rise to a large output power reduction in the last AWG, while the low-power pulses pass through the filter virtually unaltered. The principle of operation is similar to the optical regenerator proposed by Mamyshev in [6]. One important difference is, however, that the output filter here is *not* detuned with respect to the input carrier frequency. This ‘on-carrier filtering’, is found to work well for transient-impaired signals, where most of the noise is located in the ‘1’ bits. Furthermore, the method dramatically relaxes the input power requirements and avoids unwanted wavelength conversion.

After equalization, the signals are transmitted through 80 km of standard single mode fiber (SSMF). They are then reamplified, using an inline EDFA, and finally fed into 14 km DCF to compensate the chromatic dispersion of the SSMF span. The power into the SSMF and DCF is 5 dBm and 0 dBm, respectively, per channel. The detected channel is demultiplexed using a tunable bandpass filter (BPF), before entering the preamplified receiver. Clock recovery is used in the receiver. The bit-error rate (BER) is measured as a function of received OSNR and the sensitivity at a BER of 10^{-9} is noted. The transients are measured using a 100 MHz oscilloscope.



(a) Before equalizer



(b) After equalizer

Figure 3: Transients of $Data_1$ and $Dist_2$

Results and discussion

Fig. 3 (a) shows the power transients of $Data_1$ and $Dist_2$ measured right before the equalizer. The switching frequency of the AOM is seen to be sufficiently low to allow the gain of the EDFA to reach steady state after half a period. At the EDFA output, disturbing channel crosstalk has been transferred to $Data_1$, which now suffers from 48% average power fluctuations. Fig. 3 (b) shows the equalizer output power of the same channels for different levels of average channel power into the HNLF. At 15.1 dBm of HNLF power, the fluctuations of $Data_1$ are reduced to 8%, while the overshoot of $Dist_2$ is seen to have been removed at ~12 dBm of input power. The equalizer is clearly capable of removing transients.

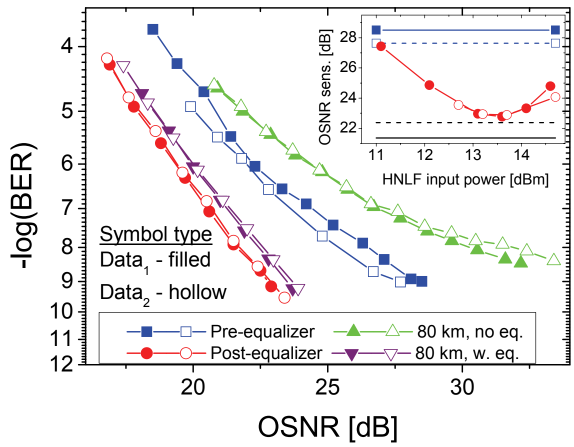


Figure 4: Bit-error rate and sensitivity for surviving 40 Gbit/s channels, $Data_1$ and $Data_2$.

The BER and OSNR sensitivity results for $Data_1$ and $Data_2$ are summarized in Fig. 4. The two channels perform very similarly. Before the equalizer (pre-), the sensitivity for both channels is very poor (~28 dB), due to the transient-impaired eye diagram. After equalization, however, the sensitivity is improved by more than 5 dB to 22.8 dB. When the two impaired channels are transmitted without use of the equalizer, an error floor appears and error-free detection becomes impossible. However, when the equalizer is used before transmission, the transmission penalty is reduced to less than 1 dB for both channels.

Conclusions

A passive, fiber-based device for equalizing and restoring signal quality of transient-impaired signals has been proposed. Successful demonstration on four 40 Gbit/s WDM channels has been performed with a reduced transmission penalty as the main result.

References

1. D. Menashe et al., ICTON 2006, paper TU.C1.2
2. Y. Sun et al., Electron. Lett., 33 (1997), p. 313-314
3. D. C. Kilper et al., JON, 7 (2008), p. 132-141
4. R. Kjær et al., IEEE PTL, 19 (2007), p. 1490-1492
5. D. C. Kilper et al., JLT, 26 (2008), p. 108-113
6. P. V. Mamyshev, ECOC 1998, Vol. 1, p. 475-476